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(54) METHOD OF PRODUCING MEDIUM MANGANESE FERRITIC-AUSTENITIC STEEL WITH A LATH-TYPE STRUCTURE, ESPECIALLY FOR FORGINGS

(57) A method of producing medium-manganese ferritic-austenitic steel with a lath structure carried out by austenitization, hot forging, cooling and heating, characterized by the fact that the initial material has a composition of 0.15-0.2% mass. C, 4.5-5.5% mass. Mn, Al and Si, with the total content of Al and Si not exceeding 2% mass, and the rest is Fe, is austenitized at a temperature 1100-1150°C, then hot forged at a temperature 950-980°C during the last deformation step during forging, then cooled in air to the room temperature, then heated to a temperature 680-700°C and held at this temperature for 30-60 min, and then cooled in air to room temperature.

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Description

[0001] The subject of the invention is a method of producing the medium manganese ferritic-austenitic steel with a lath structure, especially for forgings.
High-strength medium manganese steel is intended especially for forgings with increased ductility and crack resistance.

[0002] The method of production and chemical composition of medium manganese steels intended for forgings is presented in the publication [A. Gramlich, R. Emmrich, W. Bleck, Austenite reversion tempering-annealing of 4 wt.% manganese steels for automotive forging applications. Metals 9, 2019, 575]. The subject of the research were steels containing 0.15-0.19% C, 4% Mn, 0.5% Si, 0.02-0.2% Mo, 0.02-0.03Ti, 0.035% Nb and 0.0005 -0.005% B. Before the forging process, the steel was homogenized at a temperature 1200°C for 5 hours. Then, the forging process was carried out to produce rods, which was finished with air cooling. As a result, the steel with a martensitic structure was obtained. In the next stage, the rods were heated to a temperature of 600-675°C and held at this temperature for 1 hour to ensure the diffusion of carbon and manganese from ferrite to austenite. As a result, the steel with a ferritic structure containing retained austenite and some martensite fraction was obtained.

[0003] A method of obtaining thin sheets with a structure composed of ferrite and retained austenite was shown in the Dutch patent application US2023010877 (A1). Before the hot rolling process, the steel ingots are heated to a temperature of 1150°C for at least 1 hour, after which hot rolling is carried out. In the next stage, the sheets are heated to an intercritical annealing temperature (between A_{c1} and A_{c3}) below 700°C and they are held at this temperature for at least 5 hours, however heating times above 10 hours are preferred, in order to effectively enrich the austenite with manganese; then the steel is cooled in air or water.

[0004] The chemical composition and a method of obtaining cold-rolled medium manganese steel sheets with a structure composed of ferrite and retained austenite were shown in the Austrian patent application US2022002847 (A1), in which a range of content of chemical elements expressed in weight % is as follows: 0.03-0.12% C, 3 ,5-12% Mn, total content of Si and/or Al below 1%, optional microaddition of Ti, Nb or V, the rest is Fe and unavoidable impurities. After cold rolling, the sheet is heated to the intercritical annealing temperature (between A_{c1} and A_{c3}), which should be in the range of 684-712°C.

[0005] Due to the increasing requirements concerning high strength, ductility and crack resistance of steel forgings, it is necessary to introduce retained austenite in the form of thin films into their structure, which requires the design of time-temperature parameters of heat treatment applied after forging, which will allow for the formation of a lath-type structure containing retained austenite in the form of thin films. Forgings are characterized by a various cross-section, therefore increased hardenability is required for steel intended for forgings in order to ensure a uniform structure, both on the surface and core of the forging.

[0006] The intercritical annealing process of medium manganese steels is mainly used for semi-finished products in the form of sheets. So far, the existing material solutions concerning steels with a structure composed of ferrite and retained austenite intended for forgings do not contain aluminum addition, which together with silicon prevents the formation of cementite and additionally increases the intercritical range (the difference between A_{c1} and A_{c3} temperatures). Increasing the Mn content above 4 wt. % causes a reduction in the A_{c1} temperature, which allows for performing intercritical annealing at lower temperatures, which saves energy used in the heat treatment process. Moreover, the high hardenability of steel allowing to obtain the martensitic structure during air cooling was achieved in existing solutions by addition of Mo and/or B to the steel, which increases production costs.

[0007] The aim of the invention was to design the chemical composition of medium manganese steel and the time-temperature parameters of heat treatment applied after forging, which will allow to obtain the structure composed of ferrite and retained austenite, uniform in the cross-section of the forging showing high strength, ductility and crack resistance.

[0008] The aim of the invention is a method of producing medium-manganese ferritic-austenitic steel with a lath structure carried out by austenitization, hot forging, cooling and heating, characterized by the fact that the initial material with a composition of 0.15-0.2% mass. C, 4.5-5.5% mass. Mn, Al and Si, with the total content of Al and Si not exceeding 2% mass, and the rest is Fe, is austenitized at a temperature of 1100-1150°C, then hot forged at a temperature of 950-980°C during the last deformation step during forging, then cooled in air to the room temperature, then heated to a temperature of 680-700°C and held at this temperature for 30-60 min, and then cooled in air to room temperature.
Application of steel obtained by the method according to claim. 1 for the production of forgings.

[0009] Mn addition at a concentration of 4.5-5.5% mass increases the hardenability of steel, which allows to use air cooling after hot forging without the need to add other chemical elements increasing hardenability, such as molybdenum or boron. Manganese is a much cheaper chemical element than Mo or B, which reduces the production cost of forgings. Due to the Mn addition, it is possible to obtain a homogeneous structure on the cross-section of forgings with different thickness. Moreover, Mn is an austenite-stabilizing element, which allows to obtain more than 20% of austenite in the structure.

[0010] A low carbon content in steel: 0.15-0.2% weight has a positive effect on the impact strength and machinability of forgings. The limited C content has also a positive effect on durability of forging tools.

[0011] Al and Si alloying additions, whose total content does not exceed 2 wt.% prevent the formation of cementite, which reduces the fraction of retained austenite in the microstructure of steel and has an unfavorable effect on the impact strength. Aluminum additionally influences the expansion of the intercritical range to min. 200°C.

The A_{c1} temperature of the medium manganese steel according to the invention is not higher than 670°C and the temperature range between A_{c1} and A_{c3} is min. 200°C. The medium manganese steel obtained according to the invention shows the following structural composition: less than 2% of fresh blocky martensite, more than 20% of retained austenite in the form of films with an average thickness not exciding 300 nm and a mass content of C min. 0.4 wt.% and Mn min. 7.0 wt.%.

[0012] Retained austenite in the form of thin films prevents the initiation of microcracks, while martensite formed as a result of plastic deformation contributes to blocking the propagation of possible microcracks.

The content of alloy additions in the steel according to the invention is set to achieve a specific hardenability and an A_{c1} temperature not higher than 670°C and the temperature range between A_{c1} and A_{c3} should be at least 200°C. The chemical composition of the steel according to the invention is additionally subjected to the condition that the hardenability allows to obtain the martensitic structure during air cooling to the room temperature applied after hot forging. The chemical composition of steel should be designed to avoid the occurrence of ferritic, pearlitic and bainitic transformations during air cooling applied after forging.

[0013] The key structural constituent of steel is ductile retained austenite showing high stability determined by a carbon content min. 0.4% mas. and Mn min. 7% mas. in the form of thin films with a width less than 300 nm, which relaxes the stress or gradually transforms into martensite under operating conditions of the forging, preventing the initiation of cracks and blocking their possible propagation. The key element in designing the time-temperature parameters of the intercritical annealing process is to minimize the amount of blocky retained austenite, which initiates cracking during the operating conditions of forgings. The structure of medium manganese steel according to the invention ensures high mechanical properties compared to existing solutions.

The chemical composition of the steel according to the invention allows obtaining retained austenite in the structure with the following parameters:

- a carbon content min. 0.4 mas.%
- a manganese content min. 7 mas.%
- a volume fraction min. 20%; the rest is ferrite
- morphology in the form of films
- film thickness below 300 nm

The solution according to the invention is explained in more detail in the implementation examples.

[0014] An ingot with a chemical composition of 0.19C-5.4Mn-0.87Si-1.0Al with a cross-section of 100x100mm and a weight of 100 kg was produced using a vacuum furnace in an argon atmosphere. Then, the ingot was initially forged into a rod with a diameter of 80 mm. The forging process was preceded by austenitizing the ingot in a furnace at a temperature 1150°C for 60 minutes. The same austenitizing parameters were used during the next hot forging cycle, which was carried out in a press in two deformation steps at the following temperatures: 1100°C (I) and 980°C (II). Then, the forging was cooled in air to the room temperature. Then, the forging was heated in a furnace to a temperature 680°C and held for 30 minutes and then finally air cooled to the room temperature.

The chemical composition of medium manganese steel (wt.%) according to the invention is shown in Table 1. The mechanical properties of the steel according to the invention are presented in Table 2.

Table 1

Melt	Chemical composition, % mas.						
IA	C	Mn	Si	Al	P_{max}	S_{max}	Fe
	0.19	5.4	0.87	1.0	<0.015	0.013	balance

Table 2

	Mechanical properties of steel			
Melt	YS, MPa	UTS, MPa	TEI, %	HV10
IA	715	920	22	310

[0015] Fig. 1 shows the CCT diagram of the steel according to the invention from the melt described as IA. Fig. 1 shows that for a wide range of cooling rates 0.05-60°C/s, martensite was observed in the structure of steel. The distribution of HV hardness in Fig. 1 shows that a high hardness from 438 to 496 HV was obtained in the range of tested cooling rates, which proves the high hardenability of the steel. The temperature difference between A_{c1} and A_{c3} is 227°C. Fig. 2 shows the morphology of retained austenite in the form of thin layers with a thickness not exceeding 300 nm. The microstructure contains ferrite and retained austenite in the amount of 20%, estimated using the X-ray diffraction method. Fig. 3 is a TEM-EDS image showing differences in a Mn content (wt.%) in ferrite and films of retained austenite after the intercritical annealing process.

Claims

1. A method of producing medium-manganese ferritic-austenitic steel with a lath structure carried out by austenitization, hot forging, cooling and heating, **characterized by** the fact that the initial material has a composition of 0.15-0.2% mass. C, 4.5-5.5% mass. Mn, Al and Si, with the total content of Al and Si not exceeding 2% mass, and the rest is Fe, is austenitized at a temperature 1100-1150°C, then hot forged at a temperature 950-980°C during the last deformation step during forging, then cooled in air to the room temperature, then heated to a temperature 680-700°C and held at this temperature for 30-60 min, and then cooled in air to room temperature.

2. Application of steel obtained by the method according to claim. 1 for the production of forgings.

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EUROPEAN SEARCH REPORT

Application Number
EP 23 02 0561

DOCUMENTS CONSIDERED TO BE RELEVANT

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X	CN 115 198 191 B (UNIV INNER MONGOLIA SCI & TECH) 23 December 2022 (2022-12-23) * 0074, 0076, 0078, 0080, 0082, 0084 *	2	INV. C21D1/26 C21D6/00 C21D7/13 C21D8/00 C22C38/02 C22C38/04 C22C38/06
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 May 2024	Kreutzer, Ingo

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CATEGORY OF CITED DOCUMENTS

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